

Diagnostic efficacy of cone-beam computed tomography for mandibular fractures

Gabriele Kaeppler, DMD, PhD,^a Carl-Peter Cornelius, DMD,^b Michael Ehrenfeld, DMD, PhD,^c and Gerson Mast, DMD^d
University of Munich, Munich, Germany

Objective. The aim of the study was to determine the clinical efficacy of maxillofacial cone-beam computed tomography (CBCT) for the diagnosis of suspected mandibular fractures and to evaluate whether findings would lead to a change in treatment.

Study design. CBCT imaging was performed for 164 patients with suspected mandibular fractures (231 sites) but equivocal clinical and radiological findings (conventional radiography). Images were interpreted by oral and maxillofacial surgeons and treatment decisions based on pre and postimaging were compared. Linear regression analyses were performed.

Results. For 63.2% of sites ($n = 146$) the suspected diagnosis was confirmed by CBCT ($P < .0001$; $R^2 = 0.93$). For 4.33% of sites ($n = 10$) no fracture was identified. Additional fractures were identified in 17.75% ($n = 41$) and additional infractures in 14.72% ($n = 34$). The treatment plan was altered for 9.52% of sites ($n = 22$).

Conclusions. CBCT imaging of suspected mandibular fractures resulted in a change in the treatment plan in 9.52%. (Oral Surg Oral Med Oral Pathol Oral Radiol 2013;116:98-104)

Despite increased availability of cone-beam computed tomography (CBCT), it has received little attention for the assessment of maxillofacial injury¹ and in particular for mandibular fractures. Patient reports involving the mandible have been limited to single case studies,²⁻⁵ for intra-operative controls⁴⁻⁶ and for postoperative inspections.⁷ In some clinical circumstances the use of CBCT is now replacing multidetector computed tomography (MDCT).⁸

With regard to the mandibular fractures it has been stated that CBCT is superior to panoramic radiography as condylar and coronoid fractures and the anterior part of the mandible were more difficult to detect due to superimposition.^{2,5}

Some authors demonstrated that CBCT was superior to conventional radiographs for the detection of fracture lines of patients with a maxillofacial trauma and provided more detailed information about subtle dentoalveolar fractures.^{1,3}

Heiland et al.⁴ stated that for intra-operative imaging of a mandibular angle fracture and a bimaxillary

repositioning osteotomy CBCT offered an alternative to computed tomography (CT) related to high-contrast structures. Other authors⁹ found that CBCT was useful to detect an unfavorable sagittal split osteotomy of the mandible and to have a direct visual control of the lingual cortical bone of the mandible and the screw placement.⁶

With regard to the use of MDCT for the diagnosis of mandibular fractures, numerous authors have reported increased accuracy as compared to conventional and panoramic imaging particularly for subcondylar fractures,¹⁰ for mandible fractures,¹¹ for additional information regarding fracture displacement and comminution,^{7,12,13} and degree of displacement.^{7,14} Nevertheless some authors stated that axial CT was not recommended for angle fractures¹⁵ and for the diagnosis of minimally displaced fractures.¹³

Sirin et al.¹⁶ found no statistically significant difference between CBCT and multislice CT in artificially created condylar fractures of 63 sheep.

For implant planning the use of conventional tomograms increased the efficacy of periapical and panoramic images, with respect to the prediction of appropriate implant size, by a factor of 2.5.¹⁷ With respect to a change in the treatment plan, selected implant size

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^aProfessor, Department of Oral and Maxillofacial Radiology, Clinic for Oral and Craniomaxillofacial Surgery, Ludwig-Maximilians University of Munich.

^bProfessor, Clinic for Oral and Craniomaxillofacial Surgery, Ludwig-Maximilians University of Munich.

^cProfessor, Head, Clinic for Oral and Craniomaxillofacial Surgery, Ludwig-Maximilians University of Munich.

^dDeputy Medical Director, Maxillofacial Surgeon, Clinic for Oral and Craniomaxillofacial Surgery, Ludwig-Maximilians University of Munich.

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Statement of Clinical Relevance

Cone-beam computed tomography imaging of mandibular fractures is a recommended procedure, as it provides additional information (additional fractures in 17.75% and additional infractures in 14.72%) and leads to a change in the treatment plan in 9.52% of sites ($n = 231$).

differed on average in 89% of the cases¹⁸ when comparing panoramic and conventional cross-sectional tomography for preoperative selection of implant size.

Although it is reasonable to assume that CBCT would perform similarly to MDCT in the diagnosis of mandibular fractures, it is unclear, unlike for implant imaging, that the use of CBCT in this circumstance leads to a change in clinical efficacy, more specifically treatment plan modifications which are potentially more beneficial for the patient.

In the present study, two major study hypotheses were focused on (1) to determine if CBCT imaging for patients with equivocal clinical or radiographic findings suggestive of mandibular fracture improved diagnostic performance, and (2) to evaluate whether confirmatory, exclusional, or additional findings in these patients would lead to a change in the treatment plan.

METHODS

Subject selection

This investigation was designed as an observational prospective study.

Institutional Review Board approval existed. A justification for each radiographic examination was performed according to national guidelines.¹⁹

The sample consisted of successive patients who presented themselves to the Clinic for Oral and Craniofacial Surgery, University of Munich, with suspected mandibular trauma. Patients were thoroughly examined by 6 oral and maxillofacial surgeons and only those who had no evidence of other maxillofacial trauma and no neurological deficiency were recruited to participate in the study. Initial radiographic examination comprised panoramic imaging (Orthophos XG Plus, Sirona, Bensheim, Germany) and a postero-anterior skull radiograph (Siemens Multix Pro/Vertex/Polydoros, Siemens, Erlangen, Germany). For those patients with uncertain clinical and/or radiological findings CBCT was performed to either confirm or rule out the suspicion of mandibular fracture.

Three-dimensional radiographic imaging

CBCT was obtained using a NewTom 3G MF12 (Quantitative Radiology, Verona, Italy) and NNT Viewer Software version 3.00 (QR srl, Verona, Italy; July 2010). Volumetric images were acquired using the large field of view (FOV; 12-in FOV, 0.38 × 0.38 × 0.3 mm voxel size) and the middle FOV (9-in FOV, 0.25 × 0.25 × 0.2 mm voxel size) zoom modes.

Exposure parameters for the 12-in-FOV mode were 110 kVp, 0.5-3.99 mA, and 5.4 s, and for the 9-in-FOV mode were 110 kVp, 0.5-4.4 mA, and 7.2-9 s.

At first, 2 scout images, i.e., lateral and postero-anterior views, were taken and then a 360° scan was obtained. The total scan time was 36 s and the

reconstruction time of the volumetric images was approximately 3 min. The above-mentioned steps were repeated by the 12-in-FOV mode or the 9-in-FOV mode.

Interpretation

Suspicious clinical findings were defined as no displacement, no mobility, no asymmetry, no occlusal discrepancy, and mouth opening was feasible; suspicious radiological findings were situations with a fracture line being questionable or discontinuous (Figures 1 and 2).

The determination whether initial radiographic examinations (panoramic and PA images) were suspicious was made by a group of maxillofacial surgeons in the ambulance (assistant physician and 2 senior physicians) and was then discussed with senior physicians of the surgical procedure sector, totaling 6 oral and maxillofacial surgeons. An initial diagnosis, based on clinical and radiographic findings, was determined.

The group of OMFS was asked to provide a consensus on the number and location of the mandibular fracture(s) and the treatment plan.

Fractures with regard to the location were classified as (1) fractures of the mandibular symphysis, (2) paramedian fractures, (3) fractures of the mandibular body, (4) mandibular angle fractures, (5) fractures of the mandibular ramus, (6) condylar base fractures, (7) fractures of the condylar neck, (8) intra-capsular fractures, and (9) coronoid process fractures according to Loukota et al., Schiel et al., the AO-classification and Buitrago-Tellez et al.²⁰⁻²²

The treatment plan options included (1) no treatment, (2) clinical follow-up control, (3) arch bars and intermaxillary fixation (IMF), and (4) surgical procedure (plate osteosynthesis).

CBCT examination was performed for those patients with suspicious findings for further diagnosis. The process for the interpretation and assessment of number and location of fractures was the same as for the initial clinical/radiographic phase. CBCT images were assessed by the group of maxillofacial surgeons in the ambulance and the surgical procedure sector.

The group of OMFS was asked to provide a consensus on the number and location of fractures and most appropriate treatment plan according to the same classifications as for the initial clinical/radiographic assessment. The decisions derived from the initial assessment based on clinical/radiographic data were compared to those determined by the group using CBCT images.

With regard to the location of the fracture, a comparison of decisions resulted in (1) CBCT confirming or ruling out the presence of the suspected fracture, (2) CBCT providing additional findings related to the confirmed fracture (like displaced fragments and multiple fragments), and (3) CBCT demonstrating a new fracture not assumed before on conventional radiographs.

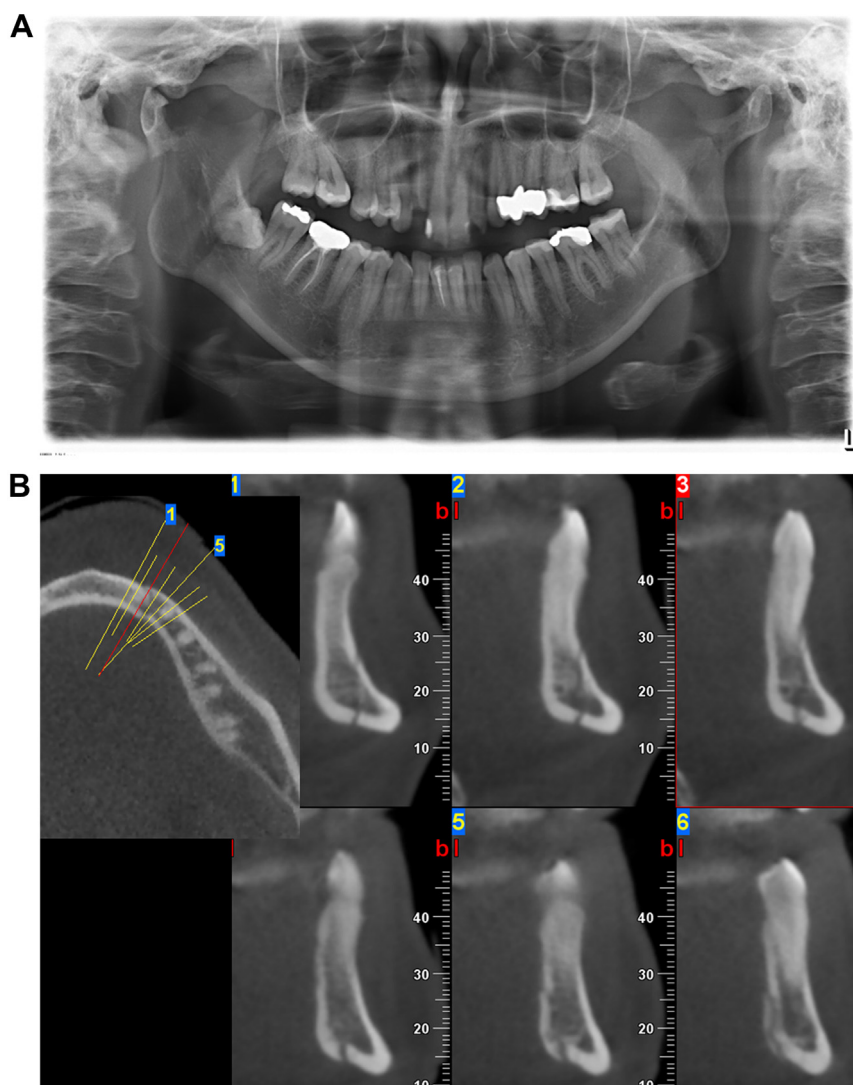


Fig. 1. (A) Paramedian fracture in the left mandible — not visible on panoramic radiograph which led to a change in treatment (surgical exploration, insertion of arch bars), also can be seen condylar base fracture on both sides. (B) Coronal view (CBCT) and topogram taken in the paramedian area.

Regarding the alteration of the proposed treatment, a comparison of decisions resulted in a definitive change in the treatment plan, defined as an additional procedure such as a surgical procedure, insertion of arch bars in either the mandible or the maxilla, IMF or withholding treatment as was the case if CBCT ruled out the presence of a fracture.

No change in the treatment plan was defined as a clinical follow-up control, prescription of a soft diet, an early functional therapy, or concurrent treatment of a fracture in another region.

Statistics

Linear regression analyses and Tukey's honestly significant difference post-hoc test were performed

using JMP (SAS Institute Inc., Cary, NC, USA). The significant effects, which led to a change in treatment, were to be established. Frequency distributions comparing fracture type from initial diagnosis with CBCT supplemented diagnosis were created. The distribution of the change in treatment by the treatment modality and by the site of the mandible was to be demonstrated. The distribution and kind of supplemental information were to be presented.

RESULTS

A total of 164 patients (231 sites totally) with suspected fractures participated in the study.

The mean age was 32 years and 5 months, the oldest patient was 96 years and 5 months old, and the

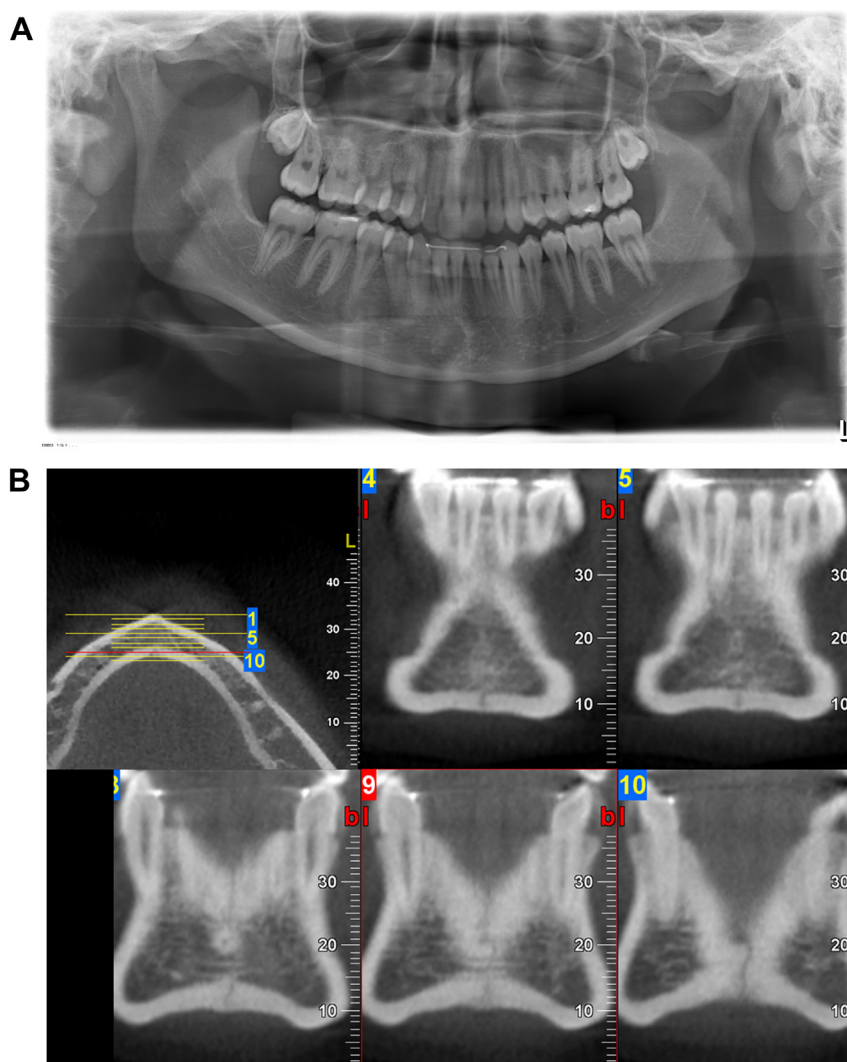


Fig. 2. (A) Fracture of the mandibular symphysis not seen before on the panoramic radiograph. (B) Coronal view (CBCT) and topogram taken in the area of the lower incisors.

youngest patient was 5 years and 3 months old. Participants were 97 men (59.15% of the patients, total $n = 164$) and 67 women (40.85% of the patients, total $n = 164$).

Only 21.95% of patients ($n = 36$, total $n = 164$) did not demonstrate a mandibular fracture. For the remaining patients (78.05%, $n = 128$, total $n = 164$), osteosynthesis was performed for 57 patients (34.76%, total $n = 164$), conservative therapy was prescribed for 55 patients (33.54%, total $n = 164$), and IMF was performed for 16 patients (9.76%, total $n = 164$).

With regard to the sites (as 1 patient could have several sites suggestive of a mandibular fracture) CBCT confirmed the diagnosis of suspected fracture based on conventional imaging in 63.2% of the sites ($n = 146$ sites, total $n = 231$). For 4.33% of the sites ($n = 10$, total $n = 231$) CBCT could not confirm the estimated diagnosis. Table I shows that for 17.75% (41 sites, total

$n = 231$), CBCT identified 41 fractures in addition to those suspected by clinical examination or observed on conventional images, for 14.72% (34 sites, total $n = 231$) CBCT identified additional infrafractures.

In the group of confirmed or additional fractures supplemental information about displaced fragments was gained in 55 sites (23.81%, total $n = 231$), and in 8 sites (3.46%, total $n = 231$) about multiple fragments.

A change in treatment was performed in the group of sites where the estimated diagnosis was not confirmed by CBCT (6 sites with a change in treatment), in the group of the additional fractures (12 sites; 3 with a surgical procedure and 9 with an IMF), in the group of the additional infrafractures (3 with an IMF), and in the group with the displaced fragments (1 site with an IMF).

Table II shows that after identification of additional fractures or infrafractures using CBCT, the preliminary

Table I. Additional findings and subsequent treatment procedure (231 sites and 164 patients)

Type of information	Provisional clinical and/or radiographic diagnosis		Additional information			
	1 Confirmed (fracture or exclusion)	2 Not confirmed	3 Additional fracture	4 Additional infraction	5 Displaced fragments	6 Multiple fragments
Sites (<i>n</i>)	146 (63.20%)	10 (4.33%)	<i>n</i> = 231			
Change in treatment	1 (IMF) (0.43%)	6 (no treatment) (2.60%)	41 (17.75%) 12 (SP = 9; IMF = 3) (5.19%)	34 (14.72%) 3 (IMF) (1.30%)	55 (23.81%) (<i>n</i> = 1, see in column 1)	8 (3.46%) 0
Rest (without change in treatment)	149 (64.50%)		Treatment already included in treatment for fractures of columns 1 and 2: <i>n</i> = 20 (8.66%) Conservative treatment (clinical follow-up control): <i>n</i> = 40 (17.31%)			

SP, surgical procedure; IMF, intermaxillary fixation.

Table II. Confirmation of the findings in conventional radiography by CBCT and change in treatment

Count Total (%)	No change	Change	Total (%)
No confirmation	64 27.71	21 9.09	85 36.80
Confirmation	145 62.77	1 0.43	146 63.20
	209 90.48	22 9.52	231

treatment plan was altered for a total of 9.52% of sites (22 sites, total *n* = 231).

For 21 sites (9.09%, total *n* = 231) with a change in treatment there was no confirmation and the additional information was gained by CBCT. For 1 region (0.43%, total *n* = 231) the fracture visible in conventional radiography was confirmed by CBCT, but the high level of displacement as an additional finding (Table I) led to a change in treatment (IMF).

Linear regression on the additional diagnostic information obtained by using CBCT (additional fractures, infractions, exclusion, and the change in treatment) indicated significant effects ($P < .0001$; $R^2 = 0.93$). The change in treatment depended on the factors of additional fractures, infractions, exclusion, confirmation, and interactions (additional fracture, exclusion). Treatment was mainly changed when additional fractures were discovered in CBCT ($P < .05$). The change in treatment for the additional infractions was not significant.

Table III shows the distribution of the changes in treatment and treatment modalities undertaken. For 6 sites (2.60%, total *n* = 231), no treatment was performed, for 7 regions (3.03%) IMF was performed, and for 9 regions (3.89%) a surgical procedure (plate osteosynthesis) was performed. So there are 22 regions (9.52%, total *n* = 231) where the treatment was changed.

Table III. Comparison of different kinds of treatments (T0, T1, T2, and T3) by change in treatment

Kind of treatment	No change (%)	Change (%)	Total (%)
No treatment (T0)	57 24.68	6 2.60	63 27.27
Clinical follow-up control (T1)	66 28.57	0 0.00	66 28.57
Insertion of arch bars, IMF (T2)	21 9.09	7 3.03	28 12.12
Osteosynthesis (T3)	65 28.14	9 3.90	74 32.03
Overall	209 (90.48%)	22 9.52	231

Kinds of treatment: no treatment, T0; clinical follow-up control, T1; insertion of arch bars and IMF, T2; and osteosynthesis, T3.

Table IV shows the distribution of the change in treatment with regard to the site. There are 10 changes in treatment for the paramedian fracture, 4 changes for the mandibular angle fracture, 2 changes for intra-capsular fractures, and 2 changes for fractures of the condylar neck.

Table V presents the differences between the sites with regard to the change in treatment. Sites (e.g., paramedian region, condylar neck, mandibular body, and intra-capsular region) which were not connected by the same letters A, B, and C were significantly different ($P < .05$). Significant differences regarding the change in treatment exist for the paramedian region, which has only letter A, and the regions of the condylar neck, the mandibular body, and the region of the intra-capsular fractures, which have only letter C. Also the coronoid process (letters A and B) is significantly different from the group with letter C.

DISCUSSION

The results of this study suggest that the use of CBCT affects the management of suspected mandibular fractures.

Table IV. Frequency of change in treatment related to the fractured mandibular region

<i>Count Total (%) Region</i>	<i>No change</i>	<i>Change</i>	
Mandibular body	21 9.09	0 0.00	21 9.09
Condylar base	17 7.36	2 0.87	19 8.23
Condylar neck	39 16.88	2 0.87	41 17.75
Intra-capsular	53 22.94	2 0.87	55 23.81
Mandibular angle	37 16.02	4 1.73	41 17.75
Mandibular symphysis	7 3.03	1 0.43	8 3.46
Coronoid process	1 0.43	1 0.43	2 0.87
Paramedian	31 13.42	10 4.33	41 17.75
Mandibular ramus	3 1.30	0 0.00	3 1.30
Total	209 (90.5%)	22 (9.5%)	231

Table V. Differences in the regions with regard to the change in treatment

<i>Region</i>	<i>*</i>	<i>*</i>	<i>*</i>	<i>Mean</i>
Coronoid process	A	B		0.500
Paramedian	A			0.244
Mandibular symphysis	A	B	C	0.125
Condylar base	A	B	C	0.105
Mandibular angle		B	C	0.098
Condylar neck			C	0.049
Intra-capsular			C	0.036
Mandibular body			C	0.500
Mandibular ramus	A	B	C	0.244

*Levels (different regions) not connected by same letter are significantly different ($P < .05$).

In the first situation the use of CBCT provides no differences in management. This can occur if no additional fractures are identified (64.50%, Table I), if additional fractures or infractures are identified using CBCT but do not affect treatment (8.66%) as they are treated together with the previously noted fracture or if additional non-displaced fractures or infractures are identified requiring conservative treatment only (17.31%, Table I). In these situations there are no differences in treatment with or without CBCT.

The second possible situation provides a change in management. This can occur if an additional fracture or infracture is identified requiring treatment of cases (fracture in 5.19% or infracture in 1.30%) or if an intended treatment is canceled as the expected fracture has been ruled out (2.60%) or if the degree of displacement requires treatment (0.43%, Table I).

In this study the diagnostic use of CBCT technology could help to identify an additional 17.75% of mandibular fractures and 14.72% infractures (Table I) and a change in treatment in 9.52% of all examined cases.

In maxillofacial trauma, patients manifest either extensive injury (e.g., soft tissue lesions, suspected intracranial bleeding, amnesia, and midface and mandibular fractures), loss of consciousness and/or depressed vital functions or ambulatory functions. For the former patients, MDCT and/or magnetic resonance imaging are a standard part of the admission protocol within the general surgical department at our institution. Ambulatory patients are admitted to our maxillofacial surgery service and CBCT imaging is performed. For the purposes of this study our sample included only ambulatory patients with suspected mandibular fracture without loss of consciousness and therefore the results and conclusions are limited to this clinical presentation.

In the present study, a medium or a large FOV has been selected as it was necessary to show both sides of the mandibular condyle. The result may be a poor image quality of the CBCT device. The problem is the fixed combination of a large FOV and a large voxel size, which does not allow selection of a large FOV and a small voxel size.

Conventional projection imaging and panoramic radiography form the baseline for the radiological assessment of ambulatory patients with suspected mandibular fracture and no loss of consciousness. However, these techniques suffer from numerous limitations such as superimposition, blurring, and distortion of anatomical structures. Posteroanterior images often demonstrate superimpositions of the mastoid process with the condyle and the mandibular ramus, especially when the patients are unable to open their mouths due to the fracture. The mental symphysis and paramedian area of the mandible are also superimposed by the cervical spine.

In panoramic radiography superimpositions of the zygomatic process, maxillary tuberosity, and the pterygoid process of the sphenoid interfere with visualization of the condyle. In addition, mandible fractures with minimal displacement or oblique fractures may not be clearly represented.

In this study, we found that in patients with suspected mandibular fracture CBCT increases diagnostic certainty to 90.5%, even in situations when a change in treatment is not made.

Decision-making by the surgeon is facilitated as the question as to whether a fracture exists or not is clearly answered by CBCT imaging. The diagnostic certainty is higher for the surgeon with CBCT imaging compared to conventional radiography. Also the outcome efficacy for the patient is higher according to level 5 of Fryback and Thornbury²³ as clinical follow-up controls with

medical CT scans providing higher radiation or redundant conventional radiographic examinations are minimized or avoided. For mandibular fractures, MDCT provides superior diagnostic accuracy to panoramic radiography¹⁰⁻¹⁵ and has been able to characterize mandibular fracture locations with greater certainty.²⁴ Because of the high soft tissue contrast, MDCT may reveal the relation of a bone fragment and the adjacent muscle, bleeding, and existence of some foreign bodies in traumatic injury. So in cases of severe injuries of soft tissue an MDCT is mandatory.

The present study shows that CBCT provides useful additional information compared to conventional imaging concerning mandibular fractures and therefore can be recommended as an alternative compared to the MDCT scan for ambulatory patients without loss of consciousness with suspected mandibular fractures.

Other possibilities for the use of CBCT exist for postoperative controls of the position of fragments and osteosynthesis plates and their relationship to endangered neighboring areas. There are open questions as to whether the quality of the surgical intervention is higher, the complication rate is lower, and healing faster with CBCT. The difficulty in answering these questions might depend on multifactorial influences, such as the experience of the surgeon, the kind of surgical procedure, the osteosynthesis systems used, the anatomical region, and the individual physical health of the patient.

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Reprint requests:

Prof. Dr. Gabriele Kaeppler
Department of Oral Radiology
Clinic for Oral and Craniomaxillofacial Surgery
University of Munich, Lindwurmstr. 2a
D-80336 Munich, Germany
gabriele.kaeppler@med.uni-muenchen.de